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Draft Report

Energy Efficiency in California High-Tech Facilities
Cleanroom Energy Design Charrette
Performed in conjunction with a confidential electronics company in San Jose, CA

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Energy Design Charrette – Confidential Electronics firm, San Jose, CA

Summary

Lawrence Berkeley National Laboratory facilitated an energy design "charrette" for a cleanroom retrofit project on September 2, 1999 for a large international electronics firm. This firm has requested that they remain anonymous in the report documenting this charrette. In this exercise, the company stakeholders, and to a limited extent the designer, participated in a process which was designed to examine the opportunity for energy saving in the HVAC air-side systems. This area was selected to demonstrate the process yet concentrate on the most energy intensive feature in the design. A four-hour "charrette" session was held which began with a discussion of the constraints encountered for this project. Next the group discussed ideas for an idealized design (with no constraints). Finally, the group attempted to apply idealized principals to the actual project. In the process, the group came up with additional ideas for attaining energy efficiency. By far, the largest energy use is with the use of cleanroom fan-filter units. Areas of focus for these components included issues related to minimizing air flow, the efficiency of the units (Watts/cfm), and ability to control the units (variability). This report discusses these areas in more detail. The group also explored opportunities within the centralized recirculation and make-up air systems. While these areas account for somewhat less energy, additional opportunities for potential savings were identified. This report of the charrette process and specific project issues was presented to the company for information which can be further examined for use on this project or used for future designs. This charrette and continuation of this process should assist in meeting the corporation's conservation goal of achieving annual energy conservation savings equivalent to 4 percent of their yearly electricity and fuel use.

Background

To develop an effective process to explore energy saving measures, an "energy design charrette" was held for the design of a cleanroom project. Charrette is a term used in the architectural community to describe a process for critiquing and improving a building design.

> The term "charrette" is adopted from the storied practice of Ecole des Beaux Arts architectural students in nineteenth century Paris who reputedly could be seen still drawing their projects until the last minute as they were carried on the "cart" or en charrette on the way to the design jury. In its modern-day adaptation, charrette refers to an intensive design workshop involving people working together under compressed deadlines.

LBNL solicited high tech firms within California to find a project appropriate for a charrette. This project was selected as representative of a typical cleanroom buildout. Ideally the timing for a charrette would be at the conceptual design stage. This project, however, was completely designed and awaiting release of construction funding before proceeding. Although the design was complete, it was decided to proceed with the charrette for several reasons:

> From owner's perspective, if significant improvements were identified there may have been time to have them incorporated due to the funding situation. In the event that it was determined that changes could not be implemented, the best practices information could be considered for future designs. In addition, the charrette process could be implemented on any future project.
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> From LBNL's perspective, the charrette process provided valuable feedback for use as a design aid and provided valuable industry feedback on a wide range of research issues such as efficient fan-filter units. The fact that the design was complete also facilitated comparisons with alternate designs.

A team of energy professionals and a facilitator were provided by LBNL to participate in the charrette. LBNL also facilitated and coordinated participation by the local utility who provided an energy consultant. The owner assembled a team of facility engineers and contract engineers familiar with the project and/or the overall site. The design team was available by teleconference. The charrette had 17 participants.

The project involved approximately 10,500 sq. ft. to be constructed in an existing operating fab. For this project, the building "shell" was not modified and constrained some of the design flexibility. The air recirculation scheme included fan-filter units arranged to achieve several different cleanliness classes. This design was the first of its kind at the San Jose complex, however, the firm has been using fan-filter designs at other facilities around the world. Temperature and humidity control was accomplished through use of an additional central recirculation unit (for temperature control), and a make-up air unit (for temperature and humidity contorl). Exhaust for the space is provided through two exhaust fans. Since the new cleanroom utilizes existing utility services such as chilled water, chilled glycol, steam, compressed air, etc., there was no opportunity to impact the design of those systems since they were not included in the project. The review team therefore decided to focus solely on the HVAC air systems which account for the majority of the non-process energy use. This focus also allowed for more in-depth discussion in the time allowed for the charrette.

Charrette Process

There are many ways to structure a charrette. To prepare for the charrette, LBNL first attended the 90% design review meeting to become familiar with the design, and the project team members. The LBNL team and the Utility consultant then reviewed design documents related to the air systems to familiarize themselves with the design.

Following this review, limited research on fan-filter units and clarification of design with the mechanical designer was undertaken.

For the charrette, the owner assembled its key stakeholders including facility engineers, energy manager, building "owner" (internal client), and facilities contract staff. This team was experienced with site issues, and most were familiar with this project. The mechanical and electrical design engineers were included by teleconference for a portion of the meeting, primarily for design intent clarification. It would have been useful to have full participation by the design team, however travel cost (from Arizona) for this limited charrette was not justified.

The team first identified constraints to achieving energy efficiency. The constraints included typical constraints present in most projects such as budget, use of standards, etc., as well as project-specific constraints such as space allocation, ceiling height, structural capacity, etc. The team then "lifted" all the constraints, and brainstormed ideas for an efficient HVAC design. These best practices ideas were not limited by any of the practical limitations on the project. Finally, the team focused on the project and sought to merge the best practices ideas with the identified constraints. The ideas generated through the charrette process for these three categories are listed below:

Constraints

- Budget – First cost construction budget governed. Various HVAC schemes were considered however selection was made based upon construction cost (with the given design assumptions on load), and did not consider energy cost. When the owner does consider operating cost, decisions are generally made based upon a two year simple payback.

- Space available – Since the new cleanroom was being constructed in an existing building shell, floor space, equipment layout space, ceiling height, etc. could not be altered easiliy. The design team could have excavated below grade, however this was not economical or technically needed.

- Electrical feeder limits- Existing electrical service to the building was not planned to be upgraded.

- Schedule – The procurement lead times for major equipment was a consideration in selection. Long lead time items were avoided.

- Continuous operation –The existing Fab had to be kept operating. Major structural upgrade for heavy air handling equipment would have impacted operations.

- Capacity of existing site utilities – New facility and process equipment for this project were constrained to use existing chilled water, compressed air, etc. This dictated design of some components.

- Structure – Because the structure could not easily be modified, the load capacity of the existing structure was a constraint which limited selection of more energy efficient options.

- Potential for natural asbestos in soil- This potential made excavation a less desirable option, and contributed to the choice of the air recirculation scheme.

- Ground water-The building is very close to ground water which also made excavation less desirable.

- Standardization – The design team was instructed to use the owner's standards which in some respects limited energy saving options.

- Future expansion – The design criteria included provision for 30-40% increase in heat loads for expansion of the process in the future.

- Factory Mutual Standards-The design must meet Factory Mutual standards. This affects ventilation and system control requirements.

- Contamination control – The company's philosophy is that cleaner is better even though a higher, more energy intensive, cleanliness class may not be required for the process.

- San Jose campus is built out- This fact constrained equipment location and coupled with structural constraints, led to air recirculation decisions.

- San Jose is a launch site for other fabs world wide. As such, the process requirements were less well defined.

- Clean rooms are built for the anticipated useful life of the process, generally < 5 years. Longer life cycle cost analyses cannot be used to justify some energy saving measures.

Idealized design

- Improve contamination control – use of ionizers, higher cleanliness class, conductive floor, shoes, gowns, Compressed air @ - 110° F dew point.

- Higher protocol – use of bunny suits

- Optimize air recirculation scheme – Use a larger air handler/ plenum, modular “tunnel modules”, fan-filter units.

- Variability - Use of VFD for recirculated air. Use of PC to remotely control fan-filter units individually rather than requiring adjustment at each unit.

- Minimize watts/cfm – Optimize airflow. Recirculate minimum amount/ air flow at 60-70 ft/min., optimize filter coverage. Remove conservatism from process load assumptions. Select efficient fan-filter unit. LBNL’s energy consultant, Supersymmetry, provided the attached comparison of fan-filter energy efficiency and air change requirements.

- Use of mini-environments

- Re- balance after adding/relocating equipment

- Raised floor design.

- Localized strip curtains for critical areas to reduce cross flow.

- Flexible design to accommodate equipment relocation during life of fab.

Current Project Design

- Investigate cost for PC control of Fan Filter Units (See item 13. Under recommendations, below). Existing scheme has individual manual control of fan speed – ie. 490 manual adjustments.

- Include energy efficiency requirement in equipment specifications. Since major equipment had not be purchased there is time to include energy efficiency requirements in the specifications.

- Investigate elimination of reheat in make-up air handler. The pressure drop across the make-up air handler seemed excessive. It was thought that design conditions could be achieved without the reheat coil in the make-up air handler.

- Use VFD on large recirculation unit – constant temperature/ variable air-volume rather than constant air-volume/ variable temperature.

- Consider outsourcing fan-filter system – Investigate lease options for clean air.

- Test for energy consumption vs. manufacturers claims – include requirement for field verification in the specification with potential penalties for non-compliance

- Optimize airflow and distribution schemes – Consider make-up air tie-in to inlet of recirculation path. Consider larger duct sizes, lower face velocities, smooth changes of direction, bottom outlet from recirculation unit. These measures will minimize pressure drop.

- Research various FFU options. Get manufacturers to guarantee unit power consumption at a given external pressure drop, filter type, and air flow. Compare units and select most efficient unit (meeting other operational requirements). Possible 50% savings on energy consumption between most efficient and least efficient.

- Use a lower face velocity on the make-up air handler. Target 3" maximum pressure drop in unit. Use face velocity of 400 fpm or less.

Recommendations

Based upon the team's suggestions and the discussion at the design charrette, we offer the following recommendations:

1. Establish a requirement to include energy efficiency as a selection criteria in product specifications.
2. Establish a procedure to perform cost-benefit analyses utilizing life-cycle cost, not simply first construction cost. This procedure would consider operating cost including energy cost, maintenance cost, etc.
3. Review company standards for cleanrooms and update them for energy efficiency considerations.
4. Consider re-balancing following major equipment moves or build-out.
5. Request (and verify) wattage required for facility system and process equipment. Determining the actual operation wattage via measurement of similar tools in operation would be ideal and allow for designing for the real load, not just the maximum possible wattage, which is often much higher than the actual operation consumption.
6. Investigate use of demand-controlled ventilation controlled by cleanliness and/or occupancy.
7. Research fan-filter units for energy efficiency. Set aggressive targets for efficiency and develop "market pull," perhaps in conjunction with other manufacturers/operators. Investigate this philosophy with IDEMA.
8. Encourage (incentivize) the architect engineer to actively contribute energy saving ideas and participate in energy charrettes early in the project. By implementing

Recommendation #2, make the operation cost/energy efficiency one of the design constraints.

9. Reevaluate the make-up air/recirculatiing air system design.
10. Modify Fan-filter unit (FFU) data sheet to include data that will allow evaluation of energy performance for proposed FFU's.
11. Include penalty clause for FFU's which don't meet submitted energy/ performance data as determined by field test after installation.
12. Carefully evaluate proposed control schemes for optimization. (Controls were not reviewed.)
13. Evaluate remote control of FFU's from a cable linked network such as Meissner + Wurst's Plug and Play BUS cabling system.
14. Evaluate controls options and resulting efficiency for various schemes of controlling the fan-filter units. VFD vs. variable-voltage, 3-phase vs DC motors etc.

Summary

The energy design charrette demonstrated a process for obtaining better energy efficiency in cleanroom applications. The charrette at this manufacturer included good participation and a lively discussion of approaches to energy issues. The process was effective in identifying a number of energy considerations and should be utilized at the early stages of any new or retrofit project. The process may have been more effective with additional participation of the design (A/E) team – especially at early stages in the design. A similar procedure might aid in the creation of general energy conservation guidelines (an energy guidelines charrette) that could be implemented via the owner's in-house standards to influence all future cleanroom design projects.